CMI

Chandler/May, Inc.

Multi Sensor Suite Performance Analysis
For
Target Detection and Classification
Final Technical Report
Phase I SBIR
Contract No. DAAH01-92-C-R106
Prepared For U.S. Army Missile Command

Real-Time Image Processing Systems

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ABSTRACT

Sensors and sensor systems are evaluated during a U.S. Army Missile Command Phase I SBIR effort to investigate the feasibility of utilizing multiple sensors to provide complimentary information to support sensor fusion concepts for the purpose of performing target classification and identification. This report investigates the performance of sensors while operating in a multisensor suite configuration and utilizes the results of this analysis in the development of design requirements for implementing a state-of-the-art sensor fusion system.

Chandler/May, Inc. has met the desired objectives of the Phase I effort and is prepared to continue with the development and implementation of a fully capable and demonstrational sensor fusion system in a Phase II effort.

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FOREWORD

This Final Report has been prepared for the U.S. Army Missile Command under SBIR number DAAH01-92-C-R106 and is entitled "Multi Sensor Suite Performance Analysis for Target Detection and Classification".

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1.0 Introduction

This Final Report documents the results of the research and analysis that has been performed during the execution of a Phase I SBIR contract entitled "Multi Sensor Suite Performance Analysis For Target Detection and Classification". The overall objective of this effort was to demonstrate through research and analysis activities the feasibility of integrating various sensors and sensor systems to provide information to sensor fusion algorithms for the purpose of performing target detection and classification and to develop a state-of-the-art architecture which could be used to fully demonstrate the advantages of sensor fusion concepts for military applications. This goal has been achieved resulting in the design of a Hardware/Software architecture which facilitates the acquisition, processing and fusion of sensor data for the purpose of performing target classification and detection applications. CMI is prepared to continue the development, integration and implementation of the necessary hardware and software components under a phase II SBIR effort.

The methodology which was implemented to perform the research and analysis was to emphasize the use of conventional sensors and sensor systems to perform sensor fusion activities in order to enhance the detection, classification and identification of potential targets. Therefore, emphasis was placed on understanding the performance characteristics and benefits of individual sensors and developing innovative methods and techniques to extract information from these sensors for performing classification and identification activities. Sensor evaluations were accomplished by utilizing an existing sensor processor architecture which was developed and implemented with limited funding resulting in basic functionality for performing sensor evaluations.

The technical approach used during the execution of this effort consisted of the identification of various standalone sensors which are typically utilized in conventional weapon systems. The benefits and disadvantages of these sensors are reviewed and discussed. Once the strengths and weaknesses of candidate sensor systems are identified and established, a set of functional requirements for utilizing these senors in a sensor suite configuration are developed. Sensor performance is evaluated through simulations and/or actual interface testing where sensor data is

acquired and limited processing is performed to demonstrate the benefits of using image processing and data fusion techniques for target classification and identification. Based on the results of this analysis, advanced applications and techniques which must be implemented to facilitate multi-sensor fusion for military applications are outlined. A Hardware/Software architecture is then developed in order to implement these advanced applications and is presented as a design which can be implemented in a Phase II effort.

In particular, section two of this report reviews the technical objectives for the Phase I effort. Various sensor types and the parameters which can be used from these sensors in the implementation of multi-sensor fusion applications are presented in section three. Also included in section three are the results of sensor simulations and interface testing activities where data from sensors was acquired and processed to demonstrate the advantages of implementing multi-sensor suite configurations. Based on this research and analysis, the requirements for the development of advanced applications are presented in section four along with a state-of-the-art hardware/software architecture which can be used to implement sensor fusion algorithms. Section five summarizes the results of the project and presents the conclusions reached in the Phase I effort. Section six outlines the plans to continue the development and implementation of a state-of-the-art sensor fusion testbed program in a Phase II effort.

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2.0 Phase I Technical Objectives

The technical objectives of this Phase I effort were to conduct sufficient research, analysis, simulations and testing of various sensors in order to support the development of a conceptual design for implementing advanced sensor fusion applications to enhance target detection and classification under various environmental conditions. To accomplish this objective, the Phase I effort has been broken down into the four tasks described below:

Task 1
Identify various sensors and the associated data which can be acquired and extracted from these sensors while operating in a multi-sensor suite configuration.

Summary of Accomplishments
Before one can optimize a sensor suite configuration, the advantages and disadvantages of using certain sensors must be understood and established. Various sensors and sensor systems, when fused with other sensor data, can offer significant improvement over systems which implement single sensor solutions for target detection, classification and identification. The results of this task is a set of functional requirements for sensors which can be used in the development of sensor fusion algorithms and applications.

Task 2
Evaluate sensors ability to provide sufficient information to accomplish data fusion with other complimentary sensors.

Summary of Accomplishments
The performance of sensors has been evaluated to determine the type of information which can be acquired and processed in real-time to facilitate target classification and identification. Limited simulations and testing activities were conducted with several sensors to demonstrate the feasibility and advantages of sensor fusion applications. Innovative methods and techniques were utilized to acquire and process sensor data.

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Task 3

Based on the results of the research and analysis conducted in tasks one and two above, develop the requirements for advanced applications which should be accomplished in order to implement a fully capable and demonstrational multi-sensor suite configuration.

Summary of Accomplishments

Advanced application requirements have been developed during the execution of the Phase I effort. These requirements include activities such as the identification of advanced image processing methods and techniques, the development of data fusion applications, as well as the development of requirements for classification, queuing and tracking algorithms.

Task 4

Develop a state-of-the-art Hardware/Software architecture which can be developed and implemented in a phase II effort for the purpose of demonstrating the advantages of sensor fusion for target classification and identification.

Summary of Accomplishments

A conceptual state-of-the-art architecture has been designed and documented based on the results and analysis which have been performed in this effort. This architecture will support the demonstration of a fully capable system which utilizes sensor fusion applications for target classification and identification. The state-of-the-art architecture developed in this task compliments the capabilities of the existing baseline sensor fusion processor system which was used in the sensor suite evaluations.

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3.0 Sensor Performance Evaluation

The basic elements which comprise a multiple sensor suite are the sensors data, data and commands input by the operator and apriori data from a pre-established validated database. The primary purpose for understanding the performance of standalone sensors is to be capable of determining under what circumstances and conditions should a sensor be used and how much weight should be applied to the validity of that sensors data when operating in a multi-sensor suite configuration. With this in mind, this section reviews the capabilities of current sensor systems and defines the type of data which can be obtained from these sensors as well as discusses how this data can be used with complimentary sensors in order to support the detection, classification and identification of targets. Results from simulations and interface testing to sensors are also presented and discussed in this section as they apply to sensor fusion applications.

3.1 Sensor Systems Overview

Multi-sensor suite systems can implement either active and/or passive modes of operation. An active mode is where the sensor system radiates a signal toward the target with the intention of observing a detectable signal to obtain information on the target as a result of the emission. Active sensors include sensors such as radars, lasers and any other devices which emit electromagnetic radiation. Passive devices, on the other hand, utilize nonemitting sensing elements to detect natural emissions from the target without emitting radiation for target illumination. The advantage of utilizing passive techniques is that they transmit no energy and therefore prevent enemy detection and advanced warning. These sensors include electro-optical devices such as T.V. and FLIR, passive acoustics and RF interferometers. This report mainly focuses on the use of passive sensor systems to assist in detection, classification and identification of potential threat targets. However, depending on the functional requirements of the system, active modes and sensors are recognized and recommended in order to enhance system performance in certain types of situations.

Table 3.1 summarizes typical sensor systems, their spectral range and their associated detectable characteristics which can be used in sensor fusion applications.

Table 3.1 Sensor Systems for Sensor Fusion Applications

Detectable Characteristics	Spectral Range	Sensor System
Acoustic Frequency	1Hz - 10 KHz	- Acoustic Detectors
		- Active/Passive Sonar
Electromagnetics	1Hz - 1 MHz	- Passive ESM Receiver
	1 - 10 GHz	- Surveillance Radars
	10 - 50 GHz	- Fire Control Radar
	30 - 300 GHz	- MMW Radar
Infrared (IR) Wavelength	3 - 5, 8-12 um	- Scanning Search and Track
		- Focal Plane Arrays
		- FLIR
Visible Light IR	1 - 10 um	- Laser Radar
	.4 - 1.1 um	- EO Sensors

Each of these sensor types have been designed and incorporated into military systems for the purpose of locating, characterizing and identifying potential targets in the presence of environmental effects and enemy countermeasures. In order to appreciate the benefits which can be gained by implementing sensor fusion techniques, a summary of sensor characteristics is presented in the paragraphs which follow.

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Millimeter Wave Radars

Millimeter-wave radars are active sensor systems which operate in the frequency band between microwave radars on the low side and infrared electro-optical systems on the high side. These systems offer improved angular resolution when compared to many microwave systems as well as improved performance in certain environmental conditions such as dust and smoke when compared to infrared systems. Millimeter-wave systems are restricted to short range applications due to the considerable amount of atmospheric attenuation encountered at short wavelengths. These radars are typically used to measure target azimuth, elevation, range, range rate and radar cross section while performing search and detection, tracking or missile terminal homing roles. The wide bandwidth (narrow pulse) typical of millimeter radars results in fine range resolution which can be used for target imaging or reduction of ground clutter returns. Millimeter wave systems also have high doppler sensitivity which results in good resolution of slowly moving targets. The range resolution capability of millimeter radars can be utilized in target recognition algorithms for obtaining range profiles of targets. These range profiles can then be compared to a library of known target range profiles for identification. The performance of these systems is generally good in all types of weather conditions with the exception of rain due to the attenuation affects encountered at millimeter-wave frequencies. These systems are normally limited to a maximum range of 5 to 10 kilometers.

Millimeter wave radar performance could be enhanced through using sensor fusion techniques to combine its capability of performing search and track functions with a thermal imagers ability to support target recognition. Passive devices such as an IRST could also be used to compliment the MMW sensors ability to perform search and track functions thus increasing range capability while maintaining a certain level of covertness to avoid enemy detection.

Laser Rangefinder

The laser rangefinder utilizes reflected laser radiation to determine target range as well as perform range rate measurements. These sensors perform fair to good in various types of weather conditions and offer good angular resolution due to narrow

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beamwidths. The laser rangefinders have a fairly low data rate (<50 Hz) and are limited in range performance with maximum range limits from 5 to 20 kilometers. Laser rangefinders, because of their narrow beamwidths, usually have poor search and track capability. However, these systems can be used in conjunction with a passive IRST system for performing large area search and after locating the target the laser rangefinder can be used to determine target range. This technology is rapidly changing and improving and appears to be a leading sensor candidate for providing range and range rate information in future military systems.

Forward-looking Infrared (FLIR)

Forward-looking infrared sensors are electro-optical imaging systems which operate in the infrared region of the frequency spectrum. These sensor systems are used to measure the temperature differences and spectral characteristics of objects within the sensors field of view. FLIR's are utilized to perform imaging, tracking and target recognition functions and perform well in most weather conditions while offering excellent angular resolution. This sensor is a passive device and has both day and night capability. EO devices such as a FLIR are generally excellent in performing target recognition functions. However, they lack the ability to provide range information therefore system performance can be enhanced by utilizing other sensors such as MMW, IRST or laser radars to provide this range information. With recent advancements in image processing hardware and software, FLIR data can be enhanced and analyzed to support target classification and identification activities. Image processing techniques which can be used to acquire and process FLIR imagery are discussed later in this report.

Infrared Search and Track (IRST)

Infrared Search and Track systems are passive devices which are primarily used to detect hot spots within a large search volume as well as provide the capability to perform tracking of designated targets. These systems are passive devices, have good angular resolution and provide both day and night capability as well as long range detection performance under clear weather conditions. Infrared search and tracking systems can fullfill both search and track mission objectives due to their ability to provide accurate angular information on potential targets. These sensors use the temperature gradients of targets against sky or a clear background for performing

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target detection. Target radiation which is received by the IRST sensor system originates from hot metal parts of grey body radiation or from combustion products of the engine. IRST sensor systems can be used in conjunction with other sensors to provide accurate detections, queuing information and tracking data for multi-sensor suite operations.

Television

This sensor system is a passive electro-optical device which is used to measure the reflection of visible electromagnetic radiation. These systems typically measure the shape and brightness of an object through pixel location and intensity values. The output of video sensors can be utilized in performing image processing functions on image data to enhance imagery and/or certain regions within an image for the purpose of analyzing data to assist in performing target classification and identification. Video sensors are typically used in military applications to perform imaging, search and detection in the wide-field of view, tracking and support of target recognition activities. This sensor offers fair performance in weather with excellent angular resolution due to the small pixel element sizes used in camera technology. Video sensors are primarily a daytime sensor only although intensified low level light television sensors can be used to provide nighttime capability with degraded contrast and resolution. Severe weather, nighttime and obscurants can significantly affect the performance of video sensor systems.

Radio Frequency Interferometer (RFI)

The RFI is a passive device which detects the emission of electromagnetic radiation typically in the 2 to 18 GHz region of the frequency spectrum. This sensor is capable of providing data on emitters such as the RF frequency, pulsewidth, pulse repetition frequency, and the azimuth to the target. RFI's can be used in search and detection roles as well as in performing crude angle tracking. The performance characteristics of RFI sensors include excellent performance in weather, fair to poor angular resolution, fairly good detection range performance and wide field-of-view coverage capability. Advantages of utilizing this type of sensor include the capability to perform passive target detection and support in target recognition activities. Disadvantages include the susceptibility to emission control and the lack of adequate ranging capability required to produce precision target tracks.

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Acoustic Sensors

Acoustic sensors are passive devices used in the detection of acoustic radiation from potential threat targets. These sensors can be used to perform search and detection, tracking and limited target recognition roles. Data which can be obtained from acoustic sensors include frequency, sound pressure level, signal-to-noise ratio and target azimuth. Based on the acoustic signature, certain attributes and characteristics of the blades and engine can be determined by performing frequency spectrum analysis on the acquired acoustic data. Performance characteristics of these sensors include good performance in clear weather and wide field of view coverage depending on the microphone characteristics and symmetry of the acoustic array. These sensors offer poor angular resolution (5 degrees or more) and are limited in range performance. Other disadvantages of this sensor include susceptibility to battlefield noise, acoustic deception techniques can limit the sensors effectiveness and the lack of ranging capability inhibits the sensors ability to provide accurate tracks.

3.1.1 Functional Requirements of Sensor Systems For Multi-Sensor Suite Applications

The sensor systems which were reviewed in the previous section is by no means an all inclusive list of sensors which can be used in multi-sensor suites but they are representative of the types of sensors which can be used in performing multi-sensor suite functions for the purpose of improving target detection, classification and identification. It is apparent from the discussions above that sensors are required to perform in all types of conditions and operating environments in support of detection, location and identification activities. To adequately perform and support these tasks, the following sensor functional requirements have been developed to assist in comparing the effectiveness of a sensors performance while operating in various situations.

1) Sensors should have the ability to operate in all types of weather conditions while maintaining acceptable performance levels
2) Sensors should be capable of supporting operations in day or night conditions
3) Sensors should have some measure of covertness and resistance to enemy countermeasures
4) Sensors should be capable of handling multiple targets
5) Sensors should be capable of providing data in support of target search, detection, classification and identification. This data includes parameters such as target azimuth, elevation, range, range rate, imagery and spectral signature information which can be fused with other sensor data in support of classification and identification.

Based on the summary of sensors performance characteristics discussed above, Table 3.2 compares the performance of selected sensors against these functional requirements by assignment of a performance rating for each sensors ability to satisfy each requirement. Six points is the maximum rating a sensor can achieve for each category and is only given if a sensor fully meets this requirement. Point assignments less than six serve as a means to compare sensor performance against each sensor requirement.

Table 3.2: Sensor System Performance Comparisons

Sensor Requirement	T.V.	FLIR	MMW	IRST	Acoustic
1) All Weather	2	4	6	4	2
2) Day/Night	3	6	6	6	6
3) Covertness	6	6	3	6	6
4) CM Resistance	2	3	5	3	3
5) Multiple Targets	4	4	3	5	2
6) Search	4	4	5	6	3
7) Detection	4	4	5	6	3
8) Classification	5	5	2	2	3
9) Identification	5	5	2	1	3

Any analysis of individual sensor performance will conclude that there does not exist a perfect sensor which can satisfy all operational requirements for accurately detecting, locating, tracking and identifying targets in all circumstances and environments. As summarized in the discussions above, some sensors are more accurate at locating and tracking objects while others perform better in providing identification information. In addition to differences in sensor performance parameters, certain sensors perform better than others in different environmental and battlefield conditions. This observation establishes the need for future military systems to incorporate the ability to combine data from multiple sensors utilizing both passive and active modes for the purpose of improving performance and overall system capabilities.

The overview of sensor systems provided above has been included in this section to identify the types of data which are provided by sensors and the associated features which can be extracted from them. A summary of the types of features which can be utilized in sensor fusion applications from selected sensors is presented in Table 3.3.

Table 3.3: Sensor Features Overview

Sensor Type	Sensor Features
1) Millimeter Wave Radar	- Distribution and range extent of potential targets
2) FLIR	- Shape (perimeter/area, aspect ratio, moments, centroid), max/min emission, texture
3) IRST	- Position (Azimuth, Elevation) - Azimuth Rate, Elev. Rate
4) Television	- Shape (perimeter/area, aspect ratio, centroids), parent-child relationships
5) Acoustic	- Frequencies, harmonics, frequency ratios, pump and generator frequencies
6) RFI	- Frequency, frequency modulation, pulse duration, pulse intervals, amplitude modulation

Features such as those listed above can be fused together to enhance and improve system performance. The primary objective and benefit of incorporating sensor fusion into new systems is to enhance the systems ability to estimate the location and identity of targets or to gather sufficient data from multiple sources to be able to make certain inferences that might not be possible with a standalone sensor system. Features such as those listed in Table 3.3 can be processed and compared against an apriori validated database of target features for performing classification and identification functions.

3.2 Sensor Evaluations

As part of this Phase I SBIR effort, several sensors were evaluated based on their ability to provide complimentary data to a fusion processor for the purpose of performing target detection, location, queuing, tracking, and target classification and identification. Several sensors were interfaced to the fusion processor and limited processing was performed to illustrate and demonstrate the type of data which can be extracted from sensors for performing multi-sensor suite activities. This section of the report discusses the methods which were used to evaluate these sensors and discusses how these techniques can be integrated together in the development of a fully demonstrational multi-sensor suite system.

In order to evaluate sensors performance and demonstrate sensor fusion concept functionality, the test configuration shown in Figure 3.1 was implemented.

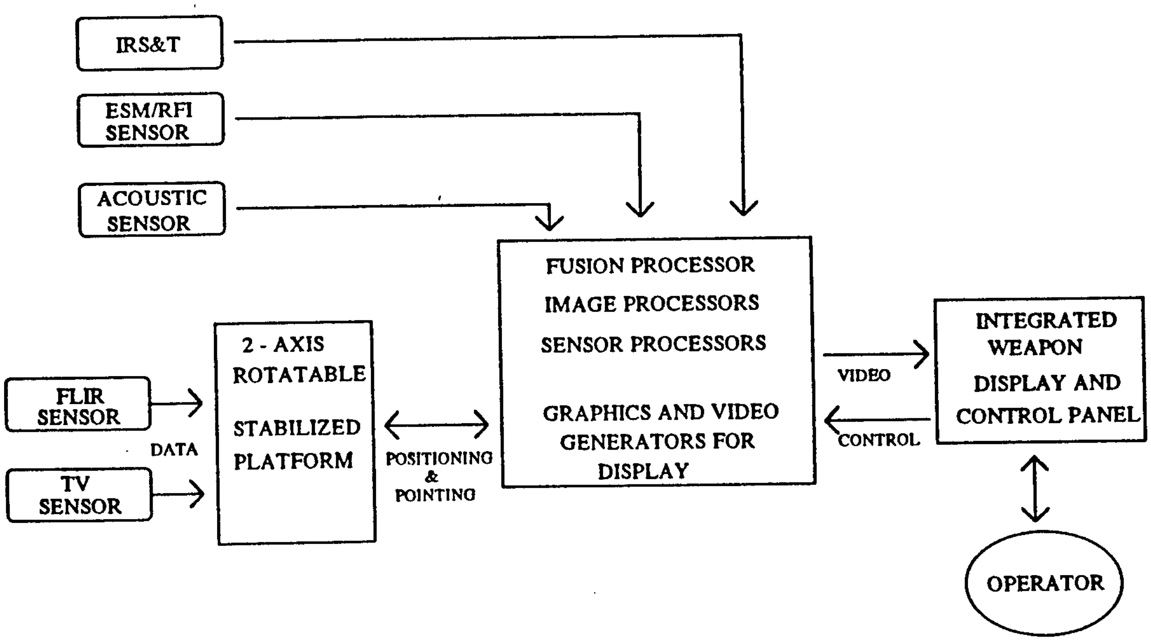

Figure 3.1: Test Configuration For Sensor Evaluation

The sensor fusion approach for the sensor evaluation process was to utilize global sensor data to provide queuing information to a position control system so that a turret could be moved to the target position and further processing could be performed using more localized sensors. This test configuration utilized a prototype data acquisition and control system to demonstrate the ability to integrate multiple sensors with a fusion processor for the purpose of demonstrating sensor fusion concepts. As shown in the figure below, dedicated real-time image processing hardware and software was used to facilitate the acquisition, processing, sensor position control and display of information for supporting sensor evaluation activities. An overview of the processing which was performed during the sensor evaluations is shown in Figure 3.2.

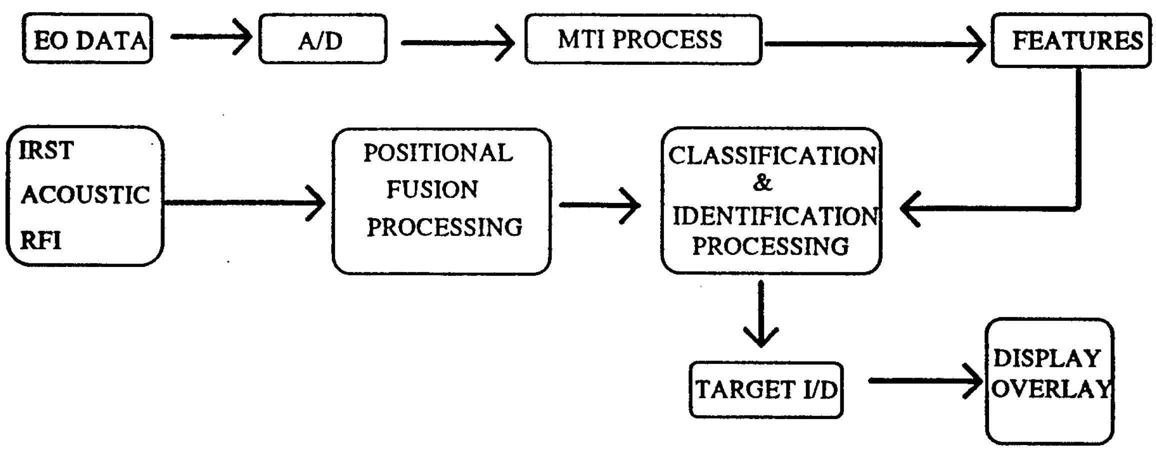

Figure 3.2: Sensor Fusion Processing Performed For Sensor Evaluations

In particular, a high speed serial input/output board was used to interface to an IRST, an acoustic array and a RFI unit. Data was acquired from all sensors, coordinate transformations, unit conversions and real-time processing activities were performed in order to generate queuing and tracking commands as well as to provide correlated target information from multiple sensors to the fusion processor. Information displayed to the operator during sensor evaluations included the results of EO sensor processing, positional information received from each sensor and results of classification and identification activities. Due to the lack of a validated database of target features for the interface testing and sensor evaluations, feature data was acquired in a learning mode in order to obtain an initial feature list database to support classification. For this activity, no range information was

provided to the processor so the features which were extracted from sensors were range independent. This interface testing and sensor evaluation was also very instrumental in the identification of software integration activities which must be performed in order to be able to fully implement and integrate multiple sensors into a sensor suite. The results of sensor evaluations and the limited processing which was performed during the execution of this effort is presented below.

A) EO Sensor Evaluation

Electro-optical (EO) sensors can be used to perform search and detection roles as well as provide imagery data which can be processed in support of identifying potential targets. In a standalone search and detection mode, EO sensors operating in a wide-field-of-view provide limited capability due to the fact that they must scan a coverage area while processing acquired data to detect objects of interest. Once a target is detected, the object must be centered in the field of view, the sensor switched to narrow field of view and then additional data can be acquired in support of target classification and identification. This process requires significant processing time and spatial coverage is limited at any given time. With additional sensors, the use of EO sensors in a multi-sensor suite configuration can enhance system performance by providing data which compliments information provided by other sensors within the same system. For example, EO sensors do not perform as efficiently as an infrared search and track sensor for detecting and locating potential targets. It was demonstrated as part of this effort that an infrared search and track sensor can be used to que an EO sensor suite at which time the EO sensors can acquire data in the narrow field of view while processing imagery information for feature generation. In this case, each of the sensors outputs compliment each other and are utilized according to optimized sensor performance characteristics. For the EO sensor suite evaluations, emphasis was placed on identifying the type of processing which could be performed to extract pertinent target data from EO sensors that would be beneficial to the performance of a sensor suite configuration.

The electro-optical sensors which were interfaced to during the execution of this contract included a COHU RS-170 camera and a Bar and Stroud FLIR. These devices were evaluated based on there ability to acquire data at various ranges and provide imagery to image processing algorithms to facilitate target detection, classification and identification. The interface requirements for both of these sensor

systems were to be capable of acquiring and processing standard RS-170 video at 30 frames a second. In order to acquire this continuous analog stream, an analog-to-digital converter was used to digitize each camera's analog signal to produce images with 512 by 482 pixel resolution. Once data was acquired into the system, filters were applied to the image to enhance image quality and image processing routines were performed to extract features from the target. The methods and techniques used during this interface testing and sensor evaluation are described below.

Data acquired from the RS-170 video and FLIR sensors are passed through a low pass filter to reduce high spatial frequency components that may be present in the image. In particular, this operation is useful for removing visual noise created by the sensor itself or by environmental conditions under which the systems are operating. Lighting conditions change throughout the day and the exact shape and appearance of the object is not known and will change depending on target aspect, therefore, a moving target indication (MTI) algorithm is used to distinguish between the target and the background. This technique uses image differencing and averaging to isolate targets which are moving over consecutive video frames resulting in a image which consist of only objects which have moved minus the background. In particular, a three frame average of differences was implemented to isolate moving objects within a video frame. This consists of subtracting frames one and two resulting in a difference frame A and subtracting frames 2 and 3 resulting in a difference frame B. Frames A and B are then averaged resulting in the final image which consist of only those objects which are moving over consecutive frames. This process is continually performed at frame rates and the results of this MTI algorithm are then used to perform shape analysis in support of identifying potential targets. Shape analysis is performed on the MTI resultant image by creating a binary image where the background or none moving pixels have a zero value and the moving objects or changed pixels have a nonzero value. This binary image represents a silhouette of the target and computations are performed to calculate video features such as centroids, area, perimeter, length, width and other geometrical features which can be used to classify and identify targets based on shape parameters relating to location, orientation and discrimination. Optimally, prior to performing classification of targets, a tracking algorithm using the IR and RS-170 video sensors in the wide field of view should be implemented to track objects so that a positional history can be maintained and only the segmented object of interest can be passed to classification.

This would decrease the amount of processing of false targets and enhance the systems ability to only process target blob information.

The interface testing of RS170 video and FLIR data during the execution of this effort illustrates that these electro-optic sensors are best utilized for target recognition and identification due to their high resolutions as opposed to search and detection roles. Testing activities were conducted at various ranges with both sensors in a four degree narrow field of view as well as in the 15 degree wide field of view. As expected, the MTI algorithm and image processing routines performed best for target classification and identification while the sensors were operating in the narrow field of view due to the higher image resolutions obtained while in this mode. In the wide field of view, the targets were visible but insufficient pixel resolution made target classification and identification difficult to achieve. It was successfully demonstrated as part of this effort that data could be acquired from a selected queuing sensor such as an acoustic array, RFI or IRST and a que command could be issued to que the EO sensor suite to the correct target position at which time the EO sensors acquire data for target classification and identification. Although much more work needs to be done in developing the software algorithms to interface to the sensors and perform processing of the data to render a decision, this effort did successfully demonstrate the use of global sensors to acquire data on target detections, process this information, and que more localized sensors to provide better signature information. This approach of configuring optimized multi-sensor suites for obtaining complimentary data sets from sensors while operating in a variety of conditions clearly has potential for increasing overall system performance.

B) Infrared Search and Track (IRST)

An infrared search and track sensor was interfaced to during this effort and limited processing was performed to demonstrate that IRST data could be acquired and processed to generate target queuing and tracking commands as well as be used in positional fusion routines for generating correlated target information to the fusion processor.

The IRST device was configured to provide current data on alerts from the IRST track processor to the fusion processor. This consisted of establishing a RS422 serial interface link at a 9600 baud transfer rate with full duplex communications protocol

without any acknowledgment. The update rate for this sensor was every 1.75 seconds. This interface was successfully implemented and communications software to acquire and process data from the IRST was developed and tested. Information which was acquired and processed from the IRST included an alert status message which contained information on specification of a new track, an existing update or a deleted track. Also included in this message field was alert identification pertaining to the track number. Outputs from the sensor which were used to que an EO platform as well as perform target tracking were target azimuth, target elevation and the associated azimuth rate and elevation rates. These sensor outputs were also used in positional fusion algorithms for performing target correlations between the IRST reports and other sensors in the system to determine the presence or absence of potential targets.

The IRST device was the most consistent sensor for providing queuing and tracking information to the fusion processor. Complimentary sensors which were observed to enhance this sensors performance were the EO sensor suite in performing target classification and identification activities and acoustic sensors which were able to detect low hovering targets when the IRST would lose track in clutter. The IRST sensor is also susceptible to certain types of enemy countermeasures and complimentary sensors may be used to maintain performance for short periods of time during countermeasure activities.

C) Acoustic

The acoustic array system was evaluated based on its ability to acquire acoustic signature data from an array of microphones resulting in reporting target azimuth to the sensor fusion processor. The acoustic system utilizes an array of microphones to collect acoustic signature data and preamplifiers to perform signal conditioning activities. An analog-to-digital converter is used to acquire the data and an array processor applies FFT techniques to process the acquired information. For the sensor evaluation, the acoustic array communications were established through an RS232 interface and data was acquired and used in positional fusion routines to provide information to the fusion processor. The results of the acoustic sensor interface testing are described below.

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The acoustic array consisted of four microphones aligned ninety degrees apart in a North, South, East and West quadrant configuration with a five foot radius between the origin and each microphone. The microphones have a lower limiting frequency of 1 and 3 Hz and a free-field response which is flat to within $\pm$ 2 dB up to 20 KHz. The sensitivities of these microphones range from 46.2 to 50 mV/Pa and a calibration algorithm was used to account for any differences between microphone sensitivities so that flat responses can be achieved between microphones. Initially, the microphones were arranged in a circular pattern which consisted of sampling the microphones in a clockwise manner (i.e. microphone 1 - North, microphone 2 - East, microphone 3 - South and microphone 4 - West). This sampling sequence resulted in inconsistent azimuth bearings therefore a cross pattern was implemented. This consisted of sampling microphones which were 180 degrees apart as opposed to the circular pattern where they are sampled at 90 degree increments (i.e. microphone 1 - North, microphone 2 - South, microphone 3 - East and microphone 4 - West). This configuration resulted in more accurate azimuth bearing reports and increased detection range capability from the acoustic system when compared to data received from the miniranger. Detection ranges for the acoustic system were dependant on the speed, weather, direction of travel and aspect angle of the aircraft. The observed detection ranges of this system during the evaluation ranged between 4 or 5 kilometers. These detection ranges were mainly accomplished during inbound test runs while detection ranges for parallel runs were harder to maintain.

Information which was acquired and processed from this sensor included frequency, target azimuth, sound pressure level, signal-to-noise ratio, sum of tolerances and the sum of weights. This sensor was mainly used in performing positional data fusion routines to assist in the detection of a target so that features could be used in classification and identification routines. The acoustic array was observed to compliment the IRST and RFI sensors by being able to detect the aircraft at low altitudes and in high clutter environments.

D) RF Interferometer

An RF Interferometer was also interfaced to and evaluated during the execution of this effort. This sensor is a passive device which is able to detect and measure the line of bearing to emitters. The RFI system includes a 360 degree amplitude direction finding coverage capability using four high and low band quadrant

antennas, three high and low band sector antennas for achieving high accuracy phase direction finding and one high and low band calibration antenna for on-line phase and frequency calibration. The system receiver consist of four channels with the ability to measure pulse parameters such as pulsewidth and pulse repetition interval. This system, when in an alerting mode, utilizes the four quadrant antennas and a receiver scan table to tune the four channel receiver. The two strongest signal returns are then compared in amplitude to determine the course direction to the emitter. For each pulse received the frequency, time of arrival, amplitude and pulse width measurements are performed. These signals are then compared to an emitter signal of interest list and if found the system will perform higher accuracy direction finding measurements. This consist of collecting multiple pulses from the emitter of interest, on-signal calibration data is acquired and calculations are performed to obtain a higher accuracy direction finding measurement through phase averaging techniques.

Information which was acquired from this sensor included the angle of arrival, the RF frequency, pulsewidth, and the pulse repetition frequency. The angle of arrival information from this sensor was used in position fusion routines which correlated RFI target positional information with other sensor data in order to achieve positional fusion of data from multiple sensors. Once positional data correlation was achieved from a suite of sensors, target features pertaining to the object of interest were passed to classification and identification routines. Due to the unavailability of RF emitters, the performance evaluation of this sensor was limited. However, the interface was implemented and positional fusion utilizing this sensor was demonstrated.

When interfacing to the acoustic and RFI sensors, it was observed that it would be advantageous to implement a more advanced and tightly coupled interface to these sensor systems where the fusion processor would be able to support "in the field calibration" of these sensors as well as use this information to more closely match features to actual observations. For example, it would be advantageous to the operator to be able to change and test variables in the field as part of calibration activities of the entire system prior to actually taking real data.

The sensor evaluations which have been described in this section successfully demonstrates the ability to integrate a variety of sensors in a multi-sensor suite

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configuration for performing sensor fusion applications. However, advanced applications must be developed in order to bring this technology to a state where military systems can realize the full benefits of implementing sensor fusion concepts through sensor integration. These advance concepts which mainly consist of sensor integration software development activities are described in Section 4.

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4.0 Advanced Applications For Multi-Sensor Suite Integration

In order to successfully implement a multi-sensor suite system, the outputs from various sensors must be fused in such a way as to represent specific and accurate estimates of the location and identity of a target. To accomplish this, many aspects pertaining to the acquisition, processing, storing and display of information must be addressed. This section describes each of these elements and outlines advanced applications and techniques which can be implemented for the purpose of demonstrating a fully capable system implementing multi-sensor suite systems. Also presented in this section is a state-of-the-art Hardware/Software architecture with off-the-shelf hardware components which can be utilized in developing and performing multi-sensor suite functions.

Figure 4.1 is a sensor fusion model consisting of the various types of processing and functions which should be performed in the development and integration of multiple sensors for performing sensor fusion applications. This diagram divides the integration of multiple sensors into the following two major functions: 1) Data Acquisition and Control, and 2) Sensor Fusion Data Processing. Each of these major components are discussed below resulting in the development of advance applications which can be developed to facilitate the integration of sensors into a multi-sensor suite configuration for target detection and classification.

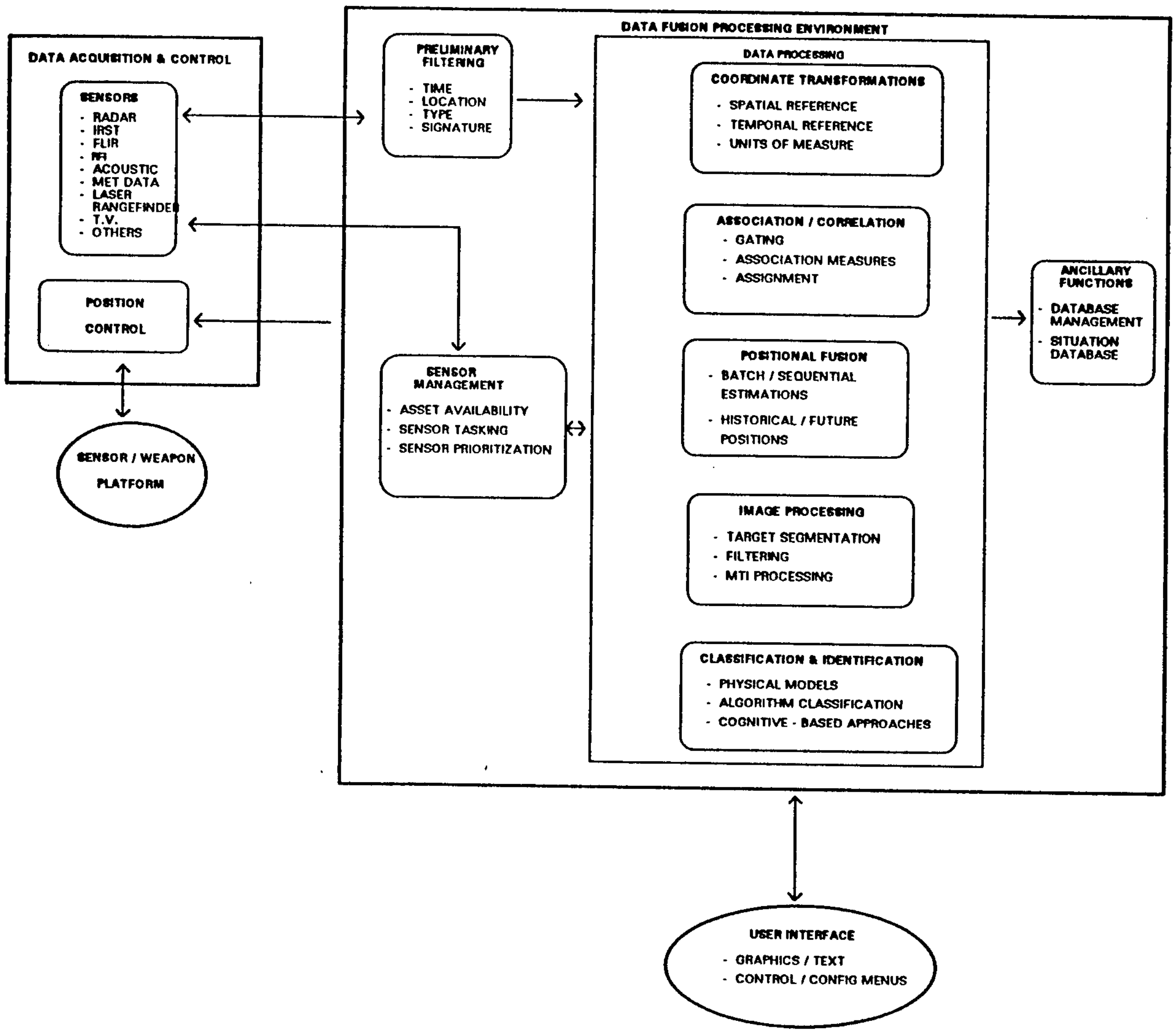

Figure 4.1: Sensor Fusion Model

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4.1 Data Acquisition and Control

The data acquisition and control function is responsible for acquiring, and managing data which is collected from each sensor as well as performing position control activities to control the positioning of sensors as a result of processed sensor inputs. In order to accomplish this function, each sensors electrical and software interface requirements should be defined including items such as data formats, message protocols, transmission rates, and sensor update rates. Preliminary filtering of input data from sensors can be used to control the flow of data into the system. Manytimes, a fusion processor can become overloaded with data from multiple sensors and not be capable of maintaining data throughput due to a sensors data rate exceeding the computational ability of the system. Therefore, sorting data according to observation time, data or sensor type and identity or signature information can be performed to control the amount of data acquired and processed by the system at any given time. Environmental data and sensor quality information can also be used to determine the amount of data acquired from sensors under different circumstances as well as establishing the priority of sensor acquisition. This methodology of grouping sensor inputs provides a means to associate data into categories and prioritize the processing of this data depending on user inputs and/or environmental data.

Data acquisition and control functions also include the determination of the availability of sensors, initializing the sensor system to perform data acquisition and prioritization of sensor tasking as well as monitoring the operational status of each sensor within the suite. Position control of sensors also requires a great deal of consideration and processing capability. For example, this activity must be capable of predicting the location of moving objects, and compute and issue pointing angle commands for sensor positioning. This is accomplished by taking the predicted position of the target and the location of the sensor and performing calculations to determine the directions and ranges required to point the sensor at the target. In addition to these activities, the data acquisition system must also be responsible for scheduling the observation intervals for sensors on each target as well as optimizing sensor resources such as moving from one target to the next.

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Advanced Application Requirements For Data Acquisition and Control

1) The system must be capable of interfacing, acquiring and processing data from various active and passive sensors. Sensor interface requirements such as data formats, data rates, update rates and message structure must be defined. This will involve utilizing RS-170, RS-232, RS-422 and 1553 interfaces to establish communications with sensors in the sensor suite. Communications software must be designed and developed to facilitate sensor communications with a fusion processor.
2) Software must be designed, developed and implemented to be capable of prioritizing sensor acquisition, processing and scheduling based on operator selection and meteorological data.
3) Software must be designed and developed to process sensor inputs for controlling position of the sensor suite. This will involve performing calculations to determine the expected azimuth, elevation and range of the target based on sensor inputs. This software must interact with other software modules in the system which are performing positional fusion and estimation functions.

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4.2 Sensor Fusion Data Processing

The data processing algorithms which are used to process acquired data play an important role in the integration of multiple sensors for the purpose of fusing data to support target classification and identification. These data processing functions include coordinate transformations, data correlations, target tracking, and classification and identification activities. These processing tasks support the fusion of data from multiple sources to establish target position, velocity, and identification features. Each of these processing elements as they apply to the integration and fusing of data from multiple sensors are discussed in the paragraphs that follow.

4.2.1 Positional Fusion Processing

Coordinate transformations and unit conversions must be performed on sensor data in order to convert to a common coordinate system. Optimally, individual sensors should adhere to a sensor fusion interface specification where coordinate transformations are performed by the sensor system prior to sending information to a sensor fusion processor. This approach will increase system performance by minimizing overhead processing activities which are required when sensor systems are not capable of performing this conversion. For example, systems which perform coordinate conversions require intimate knowledge of the sensor system in order to determine optimal methods which can be used for processing information from each sensor in such a way that the original data is not corrupted by these transformations and can be successfully used in other processing functions. Computations such as this can be computationally intensive and could involve significant processing time resulting in decreased system performance due to tasks associated with performing data transformations routines instead of more critical real-time tasks such as implementing sensor fusion algorithms.

Once data from multiple sensors has been converted into a common frame of reference, positional fusion of information must be performed in order to obtain an accurate estimate of a targets position and velocity. These positional fusion techniques are used to perform queuing and tracking functions. Input data from multiple sensors consist of parameters such as azimuth, elevation, azimuth rate, elevation rate, picture coordinates and range. Positional fusion algorithms are used to group this data from different sensors on multiple targets into observation sets

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which belong to the same target. Parametric association techniques can be used to group observations together to ensure that they belong to the same target. For example, azimuth and elevation angles from multiple sensors can be correlated with other sensor positional data to determine the presence or absence of a target at which time features can be extracted from the target and used in classification and identification routines.

Data association methods and techniques are closely coupled to tracking algorithms which are used to process multiple observations of positional data and combine them to estimate the targets future position. Before either data association or target tracking can be effectively applied to multi-sensor fusion, a major conceptual issue must be addressed as to define at what level sensor data will be combined to establish a que command or form a track on a target. The issues involved are addressed below along with examples of what was demonstrated for this effort.

In multiple sensor suite systems, a majority of the processing can be either performed within the sensor system itself and only "relevant data" is sent to the centralized fusion processor or sensor outputs can be directly interfaced to the fusion processor where data is processed internally to establish target ques and/or tracks. In the first case, each sensor maintains its own track files and combined tracks are formed within the fusion processor from this data. This approach is shown in Figure 4.2.

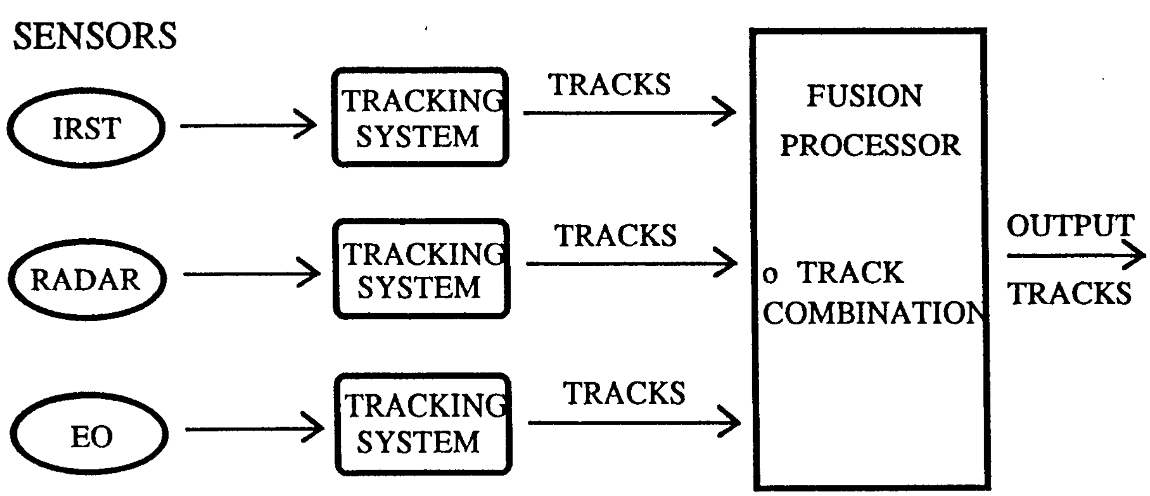

Figure 4.2
Sensor Level Fusion Processing

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This approach was taken during the interface testing and sensor evaluations described in section 3 of this report.

Advantages to sensor level approach include:

1) A reduction in the amount of data which is sent to the fusion processor is realized thus decreasing data-bus traffic, reduced computational loading and increased survivability due to distributed tracking by each sensor.
2) If a sensors performance begins to slowly degrade it will not affect the sensor level tracking capability of the other sensors although this complicates positional fusion processing due to the fact that correlation routines must be capable of deleting a sensor from the correlation scheme once it begins to degrade in performance.

Disadvantages of this approach include:

1) Less accurate correlations and tracking performance are expected. For example, sensors operating in clutter environments will most likely be sending less frequent updates on targets which will increase the probability of false correlations between sensors and decrease the systems ability to locate the target.
2) Processing of sensor level tracks to form a combined or fused track can be fairly complex. This will involve correlations between sensor level tracks and then developing an efficient method for combining these tracks into a composite track.
3) Composite tracks which have been formed from sensor level tracks may not be as accurate due to errors which could be induced from one update to another. (i.e. error independence from one update to another is not valid)

The alternative to performing sensor level queuing and tracking with multiple sensors is to interface each sensor directly to the fusion processor where raw data reports are used by the fusion processor to perform positional fusion and tracking activities. This approach is shown in Figure 4.3 below.

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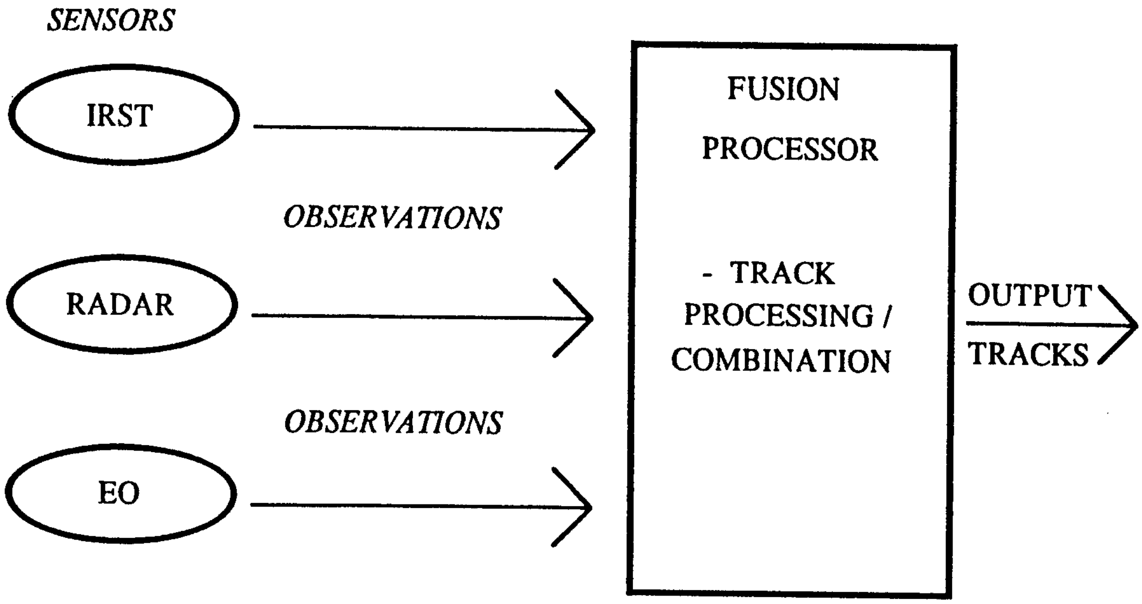

Figure 4.3: Centralized Fusion Processing

Advantages of this approach include the following:

1) More accurate tracking performance is expected due to the fact that tracks based on observations from more than one sensor should be more accurate than those established based on a partial data set received by individual sensors thus leading to fewer miscorrelations.
2) Track confirmation and continuity should be improved when implementing this method. Sensors, depending on the conditions, will vary in their ability to confirm and sustain a track therefore detections can be utilized from all sensors to improve the probability of sustaining and confirming a target track.

Disadvantages of this approach include:

1) The major disadvantage of this method is that when one or more sensors information becomes degraded it will effect the performance of the systems ability to track. This essentially results in the combination of good data with bad data which will negate the value of the good information. Conditions such as these may occur as a result of enemy countermeasures aimed at one sensor resulting in poor performance of the entire system.

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As discussed above, both of these techniques have their advantages and disadvantages although for most applications a combination of both methods is recommended in order to achieve some level of redundancy resulting in enhanced system performance.

4.2.2 Image Processing

Image processing techniques and methods can be used to process electro-optical sensor outputs to assist in performing target tracking as well as in generating features which can be used to support target classification and identification activities. These advanced applications include continued algorithm development for performing segmentation techniques, such as moving target indication, for isolating potential targets from the background resulting in only regions of interest being passed to processors for further analysis instead of an entire video frame. Additional blob analysis techniques should be applied to imagery to assist in extracting video features from EO sensors. This includes techniques to extract parent/child relationships between blobs so that only the outline of the target is used in feature analysis. Warping techniques to account for platform movement should be investigated and implemented in hardware so that tracking can be performed at the same time as moving target indication processing. Techniques for implementation of a video tracker need to be investigated and implemented so that localized sensor information can also be used to track potential targets.

4.2.3 Identification and Classification

Identification and classification algorithms are used to combine identity information such as target features which have been generated by processing various sensor data in the attempt to classify and identify potential targets. These algorithms were not the main focus of this effort and are only briefly mentioned in this report. The identification features generated from processing sensor information must be compatible as input parameters to the classification routines so that the fusion of identity information can enhance system performance. The classification algorithm which was used in this effort was an adaptation of classical nearest neighbor techniques and is called the Near-Enough-a-Neighbor Rule. This technique uses thresholds of acceptance which correspond to a known object class to classify targets. Several techniques can be used to perform classification and identification and investigation should continue with emphasis on solutions which can be optimized to process information in real-time and are within the capabilities of sensor processing hardware.

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Advanced Application Requirements For Sensor Fusion Data Processing Activities related to the Integration of Multiple Sensors

1) The system must be capable of combining sensor inputs from multiple sources and issue que and tracking commands as a result of this processing. This involves the following sensor software and integration activities:
    a) The development of a robust queuing algorithm which is capable of accepting inputs from multiple sensors and processing this information for generation of que commands. This algorithm involves methods for selecting queuing sensors based on user inputs and environmental conditions as well as having the capability and flexibility to process data from other sensor sources in order to generate secondary ques from sensors which have not been specified as the primary queuing sensor.
    b) A tracking algorithm utilizing multiple sensor inputs needs to be designed, developed, and implemented for the purpose of tracking multiple targets. This algorithm should be implemented using a combined approach between the sensor level and centralized techniques for tracking targets from multiple sensor inputs. This would consist of the development of an EO tracking algorithm as well as developing tracking routines from multiple sensor inputs.
2) The multi-sensor suite system must be have the flexibility to perform coordinate transforms and unit conversions in a real-time fashion when they are not provided by the sensor system. This will complicate processing activities which will ultimately decrease system performance due to the added overhead processing which must be performed. This involves the identification of the coordinate system for each sensor along with their associated units so that transformations can be performed to convert sensor reports into a common frame of reference without loss of data integrity.
3) Software should be developed in the integration of sensors to facilitate prioritizing sensor processing based on user inputs and environmental data.
4) Continued development of techniques which can be used to perform target segmentation should be investigated and implemented. This includes methods such as applying various filters to imagery, continued development of MTI processing to assist in defining edges for blob analysis as well as

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establishing parent child relationships between blobs so that multiple features are not generated for the same target.

5) Warping techniques need to be developed in the integration of EO sensors so that platform movement does not effect MTI processing. Combining EO sensor information through warping techniques will also assist in providing enhanced imagery to feature extraction routines.

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4.3 Conceptual Hardware/Software Architecture For Performing Multi-Sensor Suite Integration

This section of the report presents a conceptual Hardware and Software architecture which can be used to perform multi-sensor fusion techniques for the purpose of performing target classification and identification. The requirements which were presented in the previous section of this report were used as a baseline for the development of a architectural design for a VME based sensor fusion controller. This architecture facilitates the integration of multiple sensors into optimized sensor suites and can be used to fully demonstrate the benefits of implementing multi-sensor fusion concepts resulting in increased system performance.

System Overview

The sensor fusion processor architectural design consist of hardware and software elements that are required to perform data acquisition and control functions as well as provide the capability to process and display sensor information in support of target classification and identification activities in a real-time manner. In particular, this system should have all the necessary components to acquire data from multiple sensors, process imagery and positional information for target queuing, tracking and feature generation, generate position control commands to position sensors, perform classification and identification algorithms utilizing extracted features from sensors, and display pertinent target information to the operator.

The sensor fusion processor design is based on a VME based computer platform and contains several hardware components which offer significant performance improvements over the system which was used to evaluate sensor performance in this effort. The system design consist of the following functional elements: 1) Host Development Environment, 2) Real-Time Environment, and 3) chassis and peripherals. The functionality of each of these elements is discussed in the section that follows. In addition, a conceptual design drawing is presented in Figure 4.3.

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Host Development Environment

The host development environment is primarily responsible for supporting software development and networking activities. In order to support the software development and software maintenance associated with the development of a fully demonstrational multi-sensor fusion system, the host environment should consist of a standalone RISC processor board capable of supporting UNIX or a standalone workstation which can support the controller via the network. Several vendors develop these types of boards or systems incorporating state-of-the-art design techniques to meet the requirements of the host processor. As a minimum, the host system should support the following requirements:

A. The development system shall be provided by a standalone processor and separable from the real-time environment.
B. The development system shall provide a comprehensive software development environment offering extensive software development tools.
C. The development system shall facilitate network capabilities via ethernet (TCP/IP).
D. The system shall support multiusers in support of software development activities.
E. The system shall support multi-tasking
F. C, FORTRAN and ADA high level programming languages shall be supported by the development environment.
G. The development environment shall interface to a real-time operating system.
H. The development system shall provide a SCSI interface and communicate with SCSI devices.
I. SCSI devices supported shall include hard drive, floppy drive and tape drive
J. Up to 16 Megabytes of on board local RAM is required
K. The host processor shall support serial I/O and 8 bit parallel data transfers.
L. The system shall be capable of executing a window application such as X-windows.

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Real-Time Environment

The real-time processing environment shall serve as the overall system controller during the real-time data acquisition sequence. This processor should allow continuous execution of an acquisition and processing program with minimal interrupt latency times. This is required when executing a continuous video acquisition routine where data integrity is essential. The real-time environment should consist of a 680XX processor single board computer. This board must be compatible with the UNIX development environment. In order to support the execution of programs for acquiring and processing video data, the real-time system shall support the following design requirements:

A. The real-time operating system shall support multitasking and multiprocessing.
B. The system shall be both ROM and disk bootable.
C. The system shall be predictable and deterministic.
D. Must be compatible with the Host Development Environment and the Image Processing environment.
E. The processor board should have sufficient on board RAM to support processing activities
F. Support communications across the network as well as be cable of implementing multi-processor communications and data transfers.

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Data Acquisition and Control Subsystem

The data acquisition and control subsystem is responsible for acquiring data from multiple sensors, managing the information which is collected, and generating queuing and tracking commands based on processed sensor inputs. The data acquisition and control processor must be capable of performing processing routines in a real-time environment in order to maximize system performance. This environment should consist of a high speed serial input/output processor to accommodate sensor interfaces as well as a two channel dual redundant 1553 board for controlling sensor positioning. In order to support the data acquisition and control requirements of an integrated multi-sensor suite, the system must meet the following requirements.

Data Acquisition

A. The data acquisition board must be an intelligent board with an on board microprocessor for handling data communications and processing in order to perform positional fusion routines.

B. The data acquisition capability must be capable of accepting both RS-232 and RS-422 interfaces at a variety of speeds.

C. The processor board should have sufficient on board RAM to support processing activities

D. Support communications across the network as well as be cable of implementing multi-processor communications.

E. The system shall be capable of supporting special purpose processors such as array processors to support in the acquisition and processing of acoustic sensor data.

Position Control

A. Position Control system must provide the capability to communicate utilizing two 1553B channels.

B. Must be configurable to operate in Bus controller, remote terminal or passive bus monitor modes.

C. Must be capable of handling all complex 1553B protocols

D. The 1553 board must have sufficient on-board memory to support 1553 communications and processing

E. This system must be capable of supporting VME interrupts

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Image Processing Subsystem

The image processing subsystem is responsible for the acquisition and processing of electro-optical sensor data in support of tracking as well as in the generation of features for classification and identification. The image processing system should consist of a set of dedicated hardware and software elements which is capable of acquiring, and processing video data in real-time. The system should be software configurable and should support the following design requirements:

A. The system should have the capability of transferring high rate video data over a high speed video bus as well as over the VME backplane.

B. The system shall support region of interest processing.

C. The system shall have the capability to perform the following image processing functions in a real-time manner:
- Segmentation
- Feature Extraction
- Connected Component Generation
- Filtering
- Classification

D. The system shall support display of high resolution imagery

E. The system shall have sufficient video memory to support processing, display and storage activities.

Chassis and Peripherals

The inspection system will require a chassis to house the components and Peripherals to support the operation of the VME boards. The chassis and peripherals shall be ruggedized to industrial standards.

A. The overall form factor of the VME based controller should be contained in a standard 19 inch rack.

B. The chassis shall be ruggedized to industrial standards and designed to operate outdoors. Filtering of all openings should be required to prevent foreign objects and dirt from entering the chassis.

C. The chassis should be self contained with power supplies and cooling system.

F. In order to support the host development environment, the real-time system and the overall system configuration, the following peripheral will be required:

- Minimum 1.6 Gigabyte Hard Drive
- 1/4 in. Streaming Tape
- 8 mm Tape Drive
- Monochrome System Console
- High Resolution Display Monitor
- Keyboards and Mouse
- 3.5 Inch Floppy

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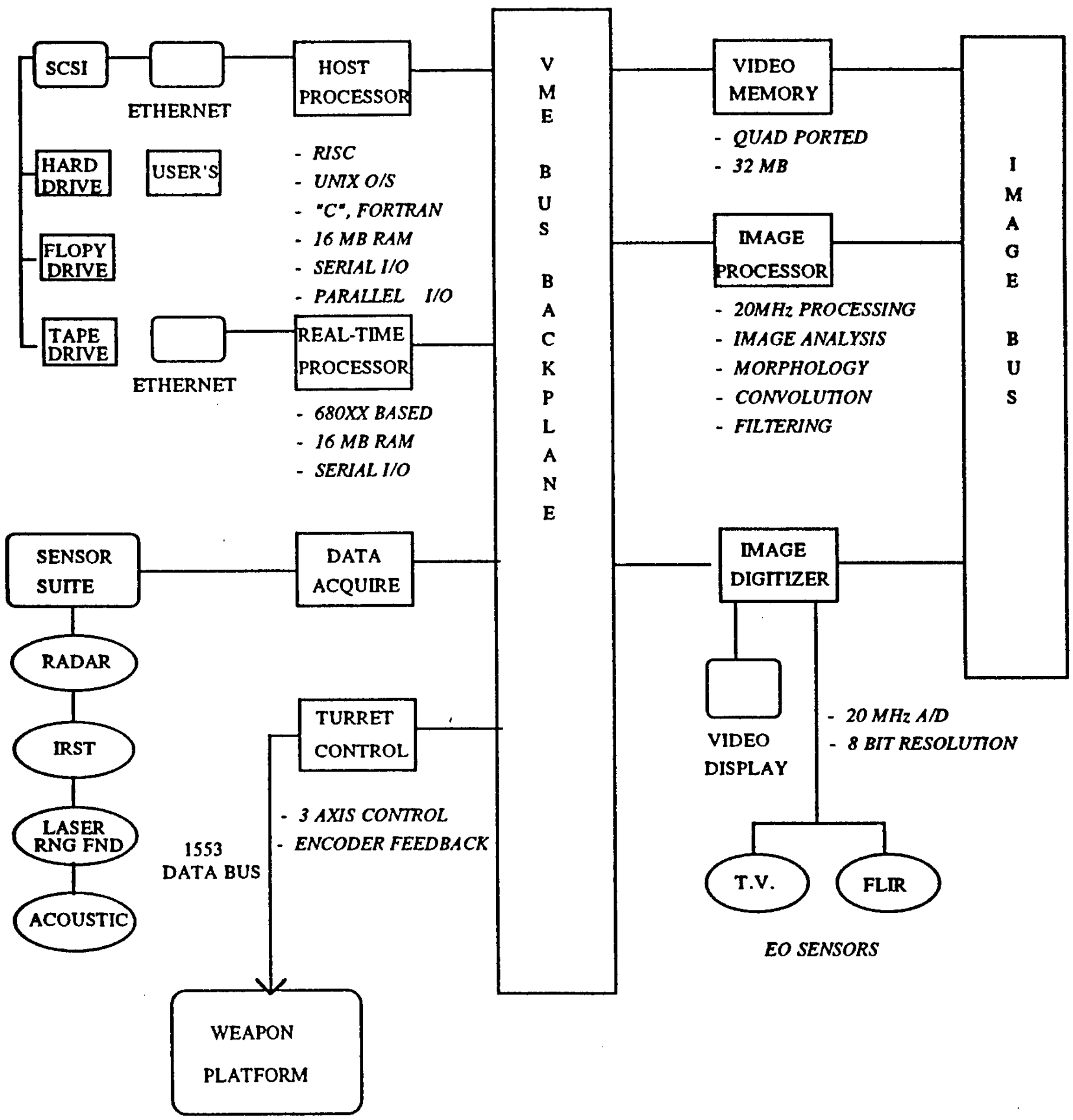
Figure 4.4

Multi-Sensor Suite Fusion Processor

Conceptual Design



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5.0 Conclusions of Phase I Effort

This Phase I effort has successfully demonstrated that various sensors can be integrated in such a way that positional fusion algorithms and feature extraction techniques can be used in providing queuing and tracking information as well as fused target data to support the classification and identification of potential targets. This concept, when implemented, will increase system capabilities and performance in a variety of battlefield environments. Although this has been demonstrated with limited funding and resources, there exist great potential for applying these techniques to the integration of sensors to accomplish enhanced system performance in the areas of detection, location and identification of potential targets. The benefits which can be realized through the implementation of these techniques include improved operational performance in a variety of conditions, extended spatial and temporal coverage, increased confidence, improved detection as well as others. The benefits which can be derived from implementing multi-sensor fusion concepts are summarized in Table 5.1.

Table 5.1: Benefits of Multi-Sensor Fusion

Benefit	Operational Advantage
Operational Performance	One sensor can contribute information while others are unavailable, jammed or cannot provide adequate coverage. This leads to: - Continued operation despite jamming - Graceful degradation - Increased Probability of Detection
Extended Spatial Coverage	- Increased Survivability - Increased Probability of Detection
Extended Temporal Coverage	One sensor can detect and acquire targets when others cannot.
Increased Confidence	Multiple sensors can confirm the same target - Engagement requires positive ID
Improved Detection	Effective integration of multiple sensors will increase the likelihood of target detections - Increased Reaction Time - Increased detection range for weapons employment - Increased Survivability
Enhanced Spatial Resolution	Improved positional data on targets decreases defensive reaction time and as well supports selection of attack profiles
Improved Reliability	The integration of multiple sensors provides redundancy resulting in graceful degradation of system performance and offers less suceptability to enemy countermeasures.

Based on the findings of the Phase I effort, it is recommended that continued work be performed in order to fully demonstrate the benefits which can be realized by integrating and processing data from multiple sensors resulting in a systems with enhanced capabilities, improved performance and are better able to adapt to changing environments.

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6.0 Plans for Phase II

CMI is prepared to continue with the development and completion of a fully capable and demonstrational integrated sensor suite in support of target classification and identification activities under a Phase II effort. The phase I effort has established the baseline requirements and design criteria for this design.

The approach recommended for the Phase II effort would be to utilize the findings of the Phase I effort in the procurement and integration of additional hardware elements which would upgrade existing hardware capabilities for interfacing to sensor systems. Once the hardware architecture has been frozen, a majority of the work performed in the phase II effort will be in utilizing the hardware capabilities to develop software algorithms and routines for truly integrating sensor system outputs into a sensor fusion processor for performing target classification and identification.

This involves the following activities:

1) Based on the phase I findings, develop a final architecture for an integrated Multi-Sensor fusion Processor.
2) Procure and integrate the necessary hardware elements to upgrade existing hardware capabilities.
3) Perform software design and development tasks which will facilitate sensor integration for the purpose of performing target classification and identification. These software development tasks have been outlined in the advanced applications section of this report.
4) Develop test plans and procedures for performing functional testing of the Integrated Multi-Sensor Fusion System.
5) Perform Functional testing of the system to demonstrate benefits of implementing sensor fusion concepts
6) Evaluate testing results to determine field performance of the system

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CMI

Chandler/May, Inc.

Certification of Technical Data Conformity

The Contractor, Chandler/May, Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. DAAHO1-92-C-R106 is complete, accurate and complies with all requirements of the contract.

10 August 1992

Jesse D. May

Chandler/May, Inc.
Jesse D. May
President

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